Design MANUFACTURING

Hitachi Super TFT-LCD Offers 140° Viewing Angle

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With the same wide ±70°or 140° viewing angle as a CRT, Hitachi's TFT-LCD aims to replace CRT monitors.

Hitachi Ltd of Japan has developed a new thin-film transistor (TFT) color liquid crystal display (LCD) technology,[1-3] called Super TFT Technology, which offers a viewing angle equivalent to that of a traditional cathode ray tube (CRT). The new technology (Fig 1) paves the way for a major new market, large-sized LCD monitors.[4]

LCDs used in notebook PCs emphasize low power consumption, small size and light weight, but there was little emphasis on the viewing angle. However for LCD monitors aiming to replace CRT monitors, the essential factors will be larger size, higher resolution and a wider viewing angle. The new Super TFT Technology seems to be a trigger to establishing that CRT replacement market.

Molecules Move Horizontally

Conventional TFT-LCDs move liquid crystal molecules using an electric field perpendicular to the glass substrate. When the molecules stand up at a sharp incline, optical characteristics change with the viewing angle, narrowing the usable visible area.

With Super TFT Technology, however, the electric field is horizontal to the glass substrate and moves molecules horizontally. Because the liquid crystal molecules rotate in parallel to the glass substrate, there is no change in optical characteristics with viewing angle. The image remains of excellent quality regardless of the viewing angle (Fig 2).

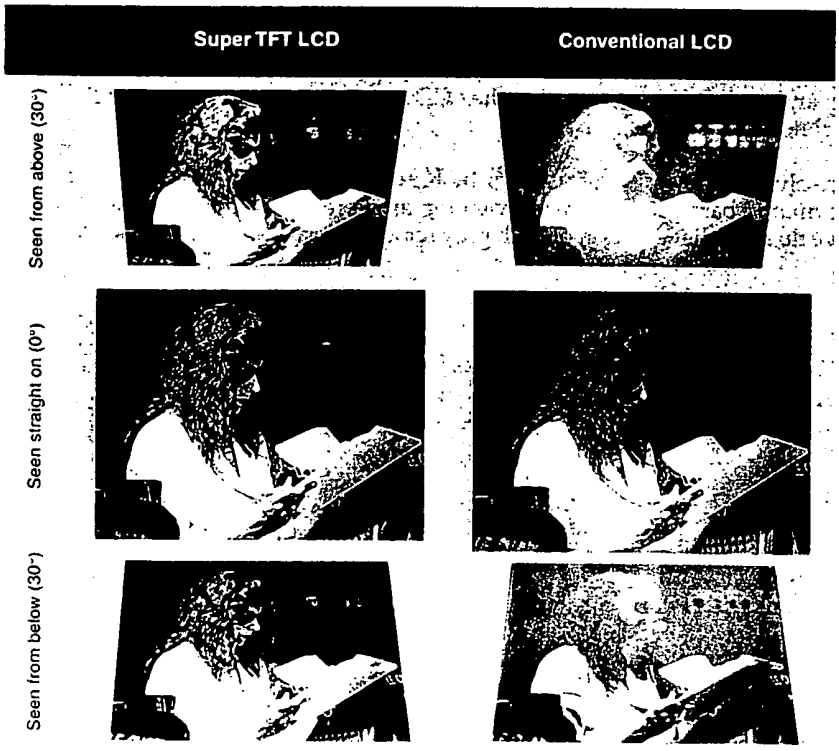

Fig 1 **Wide Viewing Angle LCD** The image from an angle is the same as seen from straight ahead. Conventional TN-LCDs suffer gray scale reversal and contrast loss when viewed obliquely because of their strong dependence on viewing angle.

Target: 50 Million CRTs

LCD monitors using Super TFT Technology are aimed firmly at the enormous CRT market. Hitachi hopes to dig into that market and gradually replace CRTs with LCD monitors.

PC shipments are growing at about 20% annually (Fig 3). The desktop PC market is about 40 million units year (Fig 4). The CRT monitor market is larger at 50 million units a year. This is because existing desktop PC users continue to replace or upgrade their CRTs.

TFT-LCDs will find promise in the CRT monitor replacement market. Even if only 10% of the 50 million units each year can be tapped, that represents sales of 5 million units. In short, TFT-LCDs may be on the verge of opening up a market roughly half the size of the existing notebook PC market.

Striving to Beat CRTs

For TFT-LCDs to begin to cut into the giant CRT market, six key per-

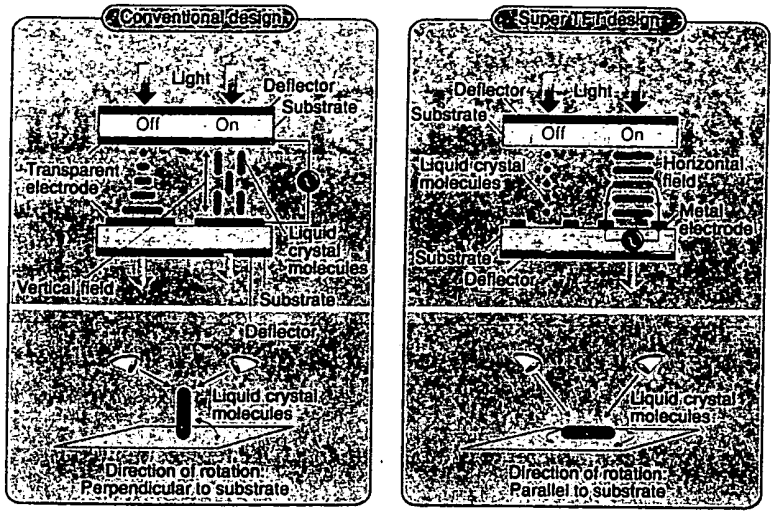

Fig 2 Horizontal Field Moves Liquid Crystal Molecules The conventional TN mode uses a vertical electric field to move the liquid crystal molecules perpendicularly to the glass substrate. As a result, when the molecules are on an incline the optical characteristics vary with the viewing angle. The new design uses a horizontal field to move the liquid crystal molecules parallel to the substrate, eliminating viewing angle dependence.

formance problems had to be met: (1) viewing angle equivalent to that of CRTs, (2) equivalent screen size to 15- to 17-inch CRTs, (3) support for Extended Graphics Array (XGA) or Super Video Graphics Array (SVGA) resolution, (4) 260,000 or 16.7 million colors displayed, (5) high-speed response suitable for motion video and (6) multiscan support. Of these, problems (2) through (6) had already been solved.

Problem (1), however, proved vexing and extremely difficult to resolve with conventional technology. There was no obvious approach.

Super TFT Technology offered a way to solve the viewing angle problem, clearing the last performance barrier.

The only remaining issue is price. But we do not believe lowering the price in itself would create a hit product. Rather, the technology is aimed at a new market where the unique characteristics of TFT-LCDs are strongly required.

The key characteristics here are low energy consumption, compactness and minimal eye strain. These characteristics do fit within industry expectations of CRT replacements with added features having a price differential of no more than 300%.

Initial Target: 17" CRTs

The 17-inch CRT monitor is the first target of new TFT-LCDs. Industry expectations are that 17-inch CRTs will emerge as the most common monitor type in the near future. It is impossible to merely compare 17-inch CRT monitors with 17-inch LCDs, however, because the CRT monitor dimensions are larger than the effective screen size, and because the viewing distances are different.

The effective screen size of the 17-inch monitor is only 15 inches. In other words, subtract two inches from the nominal monitor size. In addition, the viewer's eyes are closer to the LCD screen than to the CRT screen.

Based on these facts, Hitachi defines the equation as (CRT monitor size - 2) x 0.88 = LCD monitor size. This would mean that a 13.3-inch LCD monitor would be equivalent to a 17-inch CRT monitor (Fig 6). Hitachi believes that the LCD monitor market can be established at this size.

Using IPS to Keep Contrast

A wide viewing angle requires resolving the elimination of both gray scale reversal and contrast loss. Most of

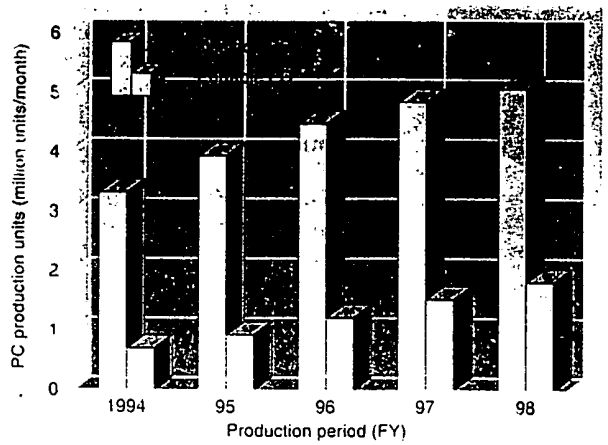

Fig 3 PC Growth 20% Annually The production volume for PCs is growing at 20% per year and notebooks account for about 20% of the total. The new LCD aims at the CRT replacement market for the remaining 80% of PCs, which are desktops.

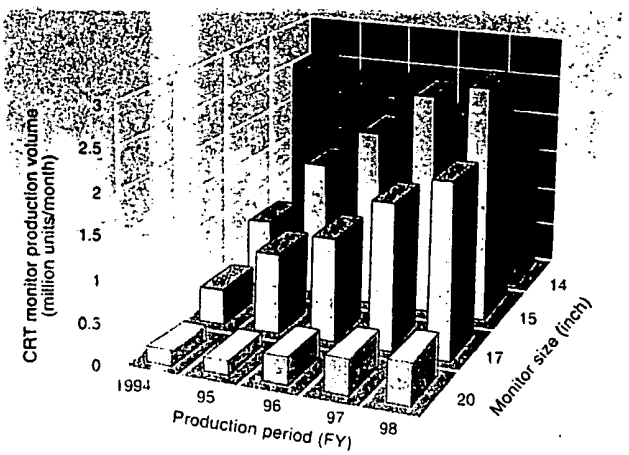

Fig 4 CRT Monitor Shipments Surpass Desktop PC Shipments Annual production volume for CRT monitors is 50 million units, higher than the 40 million desktop PCs made each year. This is because there is demand for replacement monitors independent of set sales.

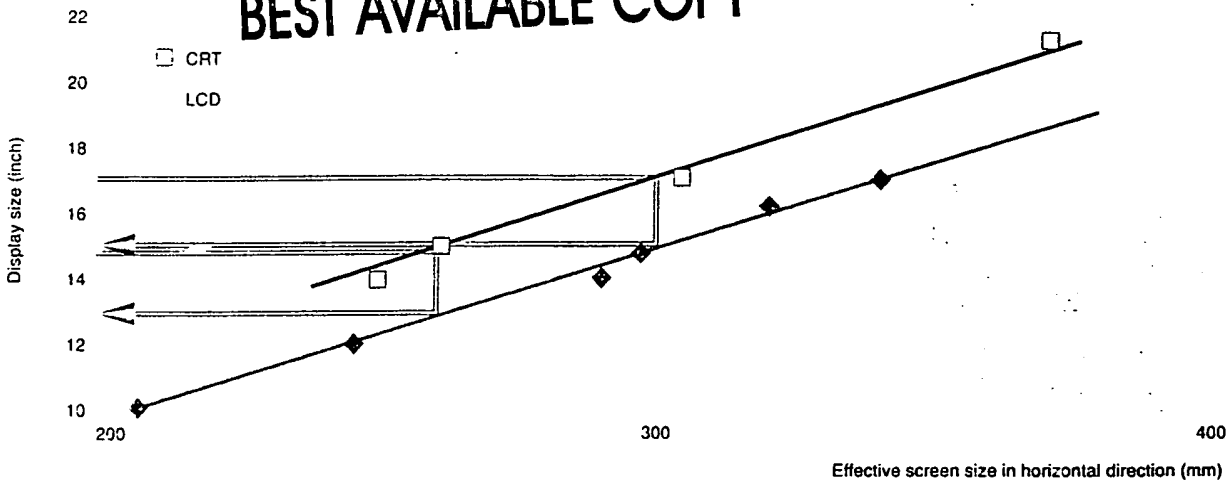

Fig 5 Initial Market: 17" CRT Monitors The LCD monitor will target the replacement market for 17-inch CRT monitors, which are expected to become the most common monitor in the near future. Because CRT monitor dimensions are larger than effective screen size and LCD monitors are used closer to the viewer, a 17-inch CRT monitor is actually equivalent to a 13.3-inch LCD monitor, claims Hitachi.

the efforts to expand the viewing angle until now have concentrated on merely widening the angle, and made little attempt to address gray scale reversal. There was essentially no activity designed to prevent loss of contrast.

Hitachi engineers paid close attention to the in-plane switching (IPS) mode in the liquid crystal as a method of eliminating both problems, because the liquid crystal molecules are rotated in the horizontal direction. The concept is not new, and indeed was proposed in the research stages for the first simple-matrix LCD, when the primary objective was an optical shutter.

The IPS mode in liquid crystals was never applied for simple-matrix LCDs because the electrode structure would have been too complex. For simple-matrix LCDs, the most common mode was twisted nematic (TN).

The next step was to try to develop a practical implementation of the IPS mode with TFT-LCDs instead of with simple-matrix LCD. Research and development efforts centered on simplifying the electrode structure and the generation and control of a suitable electric field.

Wiring Layers Halved to Two

Lowering costs was another major goal of our development, so we simplified the electrode structure, beginning by reducing the number of wiring layers.

Conventional TN mode TFT-LCDs have four layers: a gate electrode, a transparent pixel electrode, source and drain electrodes and a counter electrode. Our engineers determined that only two wiring layers were needed for IPS mode, halving the four layers in conventional TFT-LCDs.

This reduction was possible because engineers focused on cost reduction from the start.

The IPS mode uses a horizontal electric field, so the transparent pixel electrodes used to create the vertical field in TN mode displays are no longer needed. The pixel electrode can be combined into the drain electrode, eliminating one layer. The counter electrode located on the color filter side can be formed in the same layer as the gate electrode on the TFT array substrate side, eliminating a second layer.

The engineers also investigated electrode positioning within the TFT array substrate for optimum field generation (Fig 6). Positioning had to be designed to minimize the effects of noise caused by the signal line electrodes (source bus line). Two layouts for counter electrodes and pixel electrodes (drain) were compared, and it was found that when the pixel electrodes were far from the signal line electrodes capacitive coupling and noise were reduced. For this reason, the counter electrodes were positioned adjacent to the signal line electrodes.

Electrode positioning is also critical to assuring aperture ratio, because IPS mode TFT-LCDs have a much lower aperture ratio than conventional TN mode TFT-LCDs. With positioning optimized to keep the aperture ratio as high as possible, it proved better to keep the counter electrodes closer to the signal line electrodes. The closer the electrodes are to each other, the higher the aperture ratio.

High Aperture Ratio Not Essential

The engineers also analyzed the mechanism of liquid crystal molecule operation under a horizontal electric field, with an eye toward gaining a better understanding of the IPS mode in liquid crystals.

Results showed that threshold voltage for switching is closely linked to both electrode gapping and cell gapping. This meant that cell gap control precision would have to be significantly better than that used in TN mode. The brightness of the new LCD responds the same as TN-mode LCDs with effective applied voltages, meaning that existing TFT drive circuits could be used.

Based on the development of an electrode structure suitable for the IPS mode and a technology of precision cell gap control for STN-LCD, a 10.4-inch Video Graphics Array (VGA) panel was prototyped. However the aperture ratio was 35% versus 50% for existing 10-inch products. Some engineers feared the 35% ratio was too low.

However, the basic development goal was not to im-

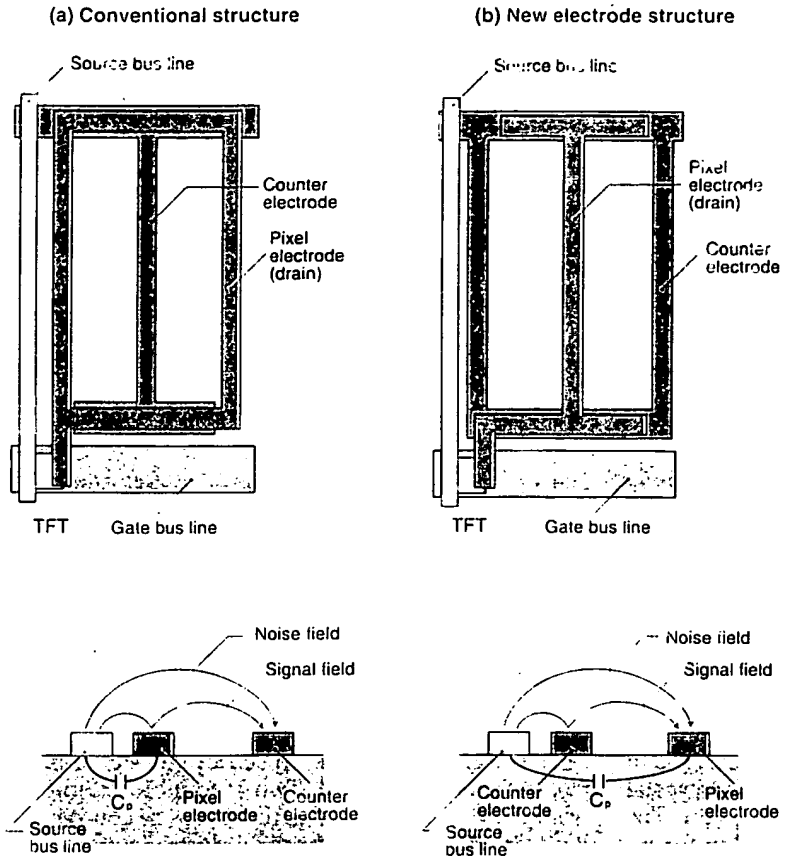

Fig 6 Electrode Structure Resistant to Noise (a) In the conventional design, the pixel electrode is close to the source bus line carrying the signal, and is easily affected by noise. (b) In the new electrode structure, the pixel electrode is separated from the source bus line, and the grounded counter electrode brought closer to the source bus line.

prove on existing notebook PC displays, but rather to replace existing CRT monitors.

Developing 13.3" XGA LCD

After the 10.4-inch LCD development, the next step was a 13.3-inch Extended Graphics Array (XGA) prototype (Table 1, Fig 7). While the pixel pitch for the VGA LCD is 0.33mm, the XGA panel achieves an even finer pitch of 0.264mm.

Supply voltage is 7V for the VGA panel, but only 5V for the XGA panel. The Super TFT Technology using the IPS mode has further potential for evolution. NEA

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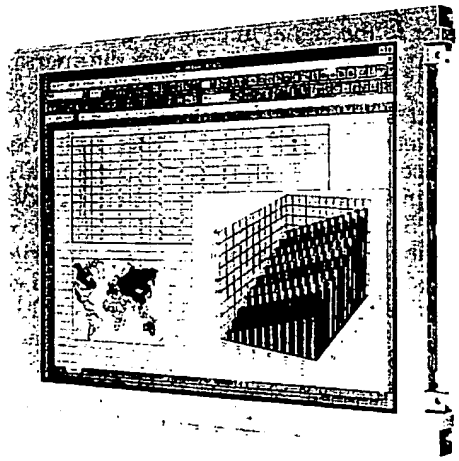

Fig 7 13.3" XGA Super TFT Color LCD The viewing angle is ±70° in both up/down and left/right directions. The power consumption of 18W is about a quarter that of the CRT. Module dimensions are 338mm x 246mm x 13mm, and it weighs 1kg. These figures are 1/50th the volume and 1/13th the weight of a CRT monitor. The LCD panel can display 260,000 colors with a screen brightness of 120cd/m² (typical), and a peak of 200cd/m².

Table 1 13.3" XGA LCD Specifications

Screen size (inch)	13.3
Effective screen area (mm²)	270 x 202
Pixel count	1,024 x 768
Pixel pitch (mm)	0.264
Display colors	260,000
Dimensions (mm³)	338 x 246 x 13
Volume (cm³)	1,080
Weight (kg)	1
Screen brightness (peak) (cd/m²)	120 (200)
Power consumption (W)	18
Top/down viewing angle (°)	±70
Left/right viewing angle (°)	±70
Contrast	100:1 or better
Response time (ms)	60
Supply voltage (V)	5